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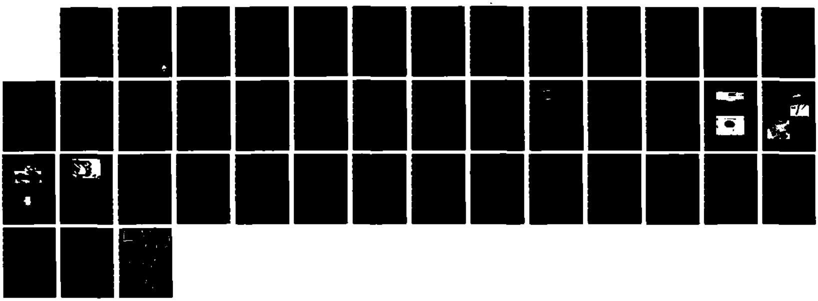

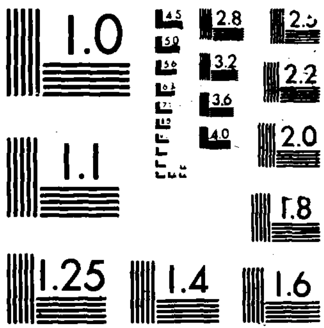
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DENTAL LABORATORY RESPIRATORY HAZARDS AND VACUUM PERFORMANCE PARAMETERS

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This study determined the vacuum performance requirements for dental laboratory vacuum systems based on the capture velocities and flow rates needed to keep respiratory dust and hazardous particle levels below the American Conference of Governmental Industrial Hygienists (ACGIH) and the Air Force Occupational Safety and Health (AFOSH) permissible exposure levels. Information is provided on the types of grinding operations performed in dental laboratories, the types of materials and instruments used in these operations, the potential hazards, and the required vacuum performance parameters. The information is designed to assist the base dental surgeon, laboratory personnel, and the base bio-environmental engineer in the design and monitoring of dental laboratory vacuum system.

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DENTAL LABORATORY RESPIRATORY HAZARDS AND VACUUM PERFORMANCE PARAMETERS

INTRODUCTION

The modern U. S. Air Force dental laboratory has the capability to fabricate many complex and intricate prostheses. In many cases a common part of this fabrication process is the grinding or polishing of the prosthesis itself, or other materials which aid in the fabrication process. The grinding and polishing procedures may generate hazardous respiratory particles and dust which have the potential to adversely affect the long-term health of laboratory personnel. Laboratory vacuum systems are intended to capture the potentially hazardous substances during the grinding procedures to ensure that they are not released into the room air.

The U.S. Air Force Occupational Safety and Health (AFOSH) Standards specify room air limits for exposure to these various hazardous substances and respiratory dust. The base bioenvironmental engineer (BEE) is tasked with ensuring that these standards are achieved and maintained. Unfortunately, while the performance parameters required of vacuum systems to meet the standards for industrial grinding operations are well defined, there exists no information on what vacuum performance parameters are required to ensure the desired air quality is maintained in the dental laboratory. Consequently the base BEE must try to apply existing industrial standards in a common sense approach to the dental laboratory environment to which he may have little practical knowledge. The result is often confusion for both the BEE and the dental personnel since the environment and types of procedures performed in a dental laboratory are different than those in an industrial setting.

The purpose of this study was to determine what vacuum performance parameters are required for various dental laboratory applications. We hope this information will provide guidance to the BEE, the base dental surgeon, and dental laboratory personnel so that laboratory vacuum systems can be adequately designed to eliminate potentially hazardous substances from the room air and properly monitored to ensure their continued effectiveness.

PHASE I - HAZARD IDENTIFICATION

Methods

Identification of Laboratory Materials

The first step in determining the required vacuum performance parameters is to identify the hazardous substances that the vacuum system must be designed to capture. With the assistance of an experienced laboratory technician, an experienced prosthodontist, and an experienced dental laboratory officer, a list of materials which are subjected to grinding operations was developed. In addition, grinding stones and other instruments

used to perform the grinding operations were placed on the list. Air Force Manual 162-6, covering dental laboratory operations, was used as a reference during the generation of the list (1).

Brand name products representing common examples of the materials and instruments in each category were identified. Stocklisted items were listed first, and information was gathered concerning the supplier of products for that stocklisted item. Also included were brand name materials and instruments that the laboratory technician and prosthodontist indicated were in common usage. The precious metals used for fixed prosthodontics, both the higher gold content alloys currently being used and their potential alternates with lower gold contents, were included.

Identification of Hazards

To determine the hazard potential from each grinding operation, information on the constituents of each material and instrument was required. To obtain this information, a Material Safety Data Sheet was requested from the manufacturer for each material or grinding instrument (Fig. 1). The data sheets list the name, general formula, hazardous ingredients, physical data, fire hazard data, health hazard data, reactivity data, spill or leakage procedures, and information on special precautions or protection required. The manufacturer is required by law to provide a Material Safety Data Sheet, if requested, on any product which is determined a potential hazard.

Following the receipt of the Material Safety Data Sheets, the Dental Investigation Service (DIS) in conjunction with the Occupational Environmental Health Laboratory (OEHL) reviewed the information and compiled a list of the hazardous substances which could be generated during dental laboratory grinding operations. Besides the concern about specific hazardous substances, any substance subjected to grinding procedures has the potential to produce respirable dust in excess of allowable limits. The compilation of potential hazards from this phase of the study was used during phase II of the evaluation to determine which grinding procedures would be used as worst case examples for determining the required laboratory vacuum performance parameters.

Results

The list of product categories and the brand names of the products used to determine the potential sources of hazardous particles are shown in Table 1.

Table 2 lists the constituents of the materials and the instruments as determined by the Material Safety Data Sheets received from the manufacturers. Those ingredients annotated with a * indicate hazardous substance for which a threshold limit value (TLV) has been established. The TLV represents the maximum allowable level to which a worker can be constantly exposed during a normal 8-h workday. The TLVs for each of the hazardous substances and for nuisance dust according to the American Conference of Governmental Industrial Hygienists (ACGIH (2)) are listed in Table 3. The TLV for total dust of any type is 10.0 mg/m^3 and for respiratory dust it is 5.0 mg/m^3. The U.S. Air Force uses one-half of the ACGIH TLV as its action level for ensuring air quality in the workplace.

Note that the most hazardous constituent of any material used in the laboratory is beryllium which has a TLV over 2000 times less than that allowed for simple respiratory dust. Fortunately beryllium exists as only a small percentage in certain alloys (less than 2%). The major constituents such as nickel, chromium, and cobalt have TLVs only 5 to 100 times less than the TLV for dust. The TLV for respiratory dust was used as the baseline for all procedures where the TLV of the substances exceeded the 5 mg/m^3 allowed for respiratory dust.

In many instances the information received from the manufacturers on the Material Safety Data Sheets was incomplete or erroneous. In many cases the major constituents were not listed or, if they were listed, their percentage in the material was not indicated. Several manufacturers indicated that there were no hazardous substances in the products, and therefore provided no Material Safety Data Sheets. In some instances, where the hazardous substances were listed, incorrect values for the TLV were given. It appeared that concern over proprietary formulations and a general unwillingness to provide complete information summarized the quality of responses received. The investigators had to turn to other sources for substantiation of the information received and for additional information required to accomplish this study. For those individuals interested in the constituents of the various dental crown and bridge alloys, excellent sources are USAFSAM reports on casting alloys (3,4).

The information gained under this phase was used in Phase II to help determine which grinding operations would be considered as the "worst case" examples when determining the required laboratory vacuum performance parameters.

PHASE II - VACUUM REQUIREMENTS

Identification of Grinding Operations

To ensure the proper performance of a vacuum system under all conditions, the vacuum system must be sized for the worst possible case. However, dental laboratories have several distinct types of equipment used for specialized grinding operations. To ensure that the performance parameters obtained from this study were relevant, dental laboratory grinding equipment which had the potential for requiring a vacuum system was divided into four general categories:

- High-speed bench lathe--A 20,000-rpm lathe used almost exclusively for metal framework grinding and finishing and usually comes with a built-in port for attachment to a central vacuum system.

- Slow-speed bench lathe--A dual speed 1750/3500-rpm lathe used for a variety of grinding, finishing, and polishing operations.

- Laboratory hand engine--An air-driven or electric handpiece used by most technicians at their individual workbench.

- Stand-up equipment--Includes equipment such as the shell blaster and microblaster which may require an external vacuum source.

For each type of equipment, the types of grinding procedures performed on that equipment were listed in order to assess the potential hazards associated with the grinding procedure. Table 4 lists the grinding operations performed on each category of equipment, and the materials and instruments used to perform that operation. This list was not meant to be totally comprehensive, but to reflect those procedures most likely to be performed on that category of equipment.

Using experienced personnel from the Dental Investigation Service, OEHL, and USAF area dental laboratories, "worst case" grinding conditions were developed for each category of equipment. These "worst case" conditions are listed in Table 5 and the estimated "worst case" frequencies are identified for a small, medium, and large area dental laboratory.

These conditions were used during the evaluation portion of this study for the determination of the required laboratory performance parameters. Specifically the following "worst case" conditions were chosen for each type of equipment:

Equipment type	Grinding operation	Hazard	Max frequency
High-speed bench lathe	Finishing and polishing a removable partial denture (RPD) framework	Metals	8 RPDs daily
Slow-speed bench lathe	Keying casts and trimming dies	Dust	8 sets daily
	Finishing porcelain	Silica	15 units daily
Hand engine	Keying casts and trimming dies	Dust	8 sets daily
	Finishing porcelain	Silica	15 units daily
Stand-up equipment	Not applicable - size according to manufacturer's specification.		

The dust hazard from keying casts and trimming dies was considered to be a more hazardous situation than the finishing and polishing of crowns and bridges due to the lower amount of respiratory dust generated when finishing fixed prosthesis compared to grinding on gypsum products. As a check, the grinding on pure fired porcelain was added as a condition since the TLV for silica is comparable for that of nickel and cobalt which are only partial constituents of the dental alloys. In the event the services switch from high gold content alloys to lower gold alloys with beryllium and high amounts of nickel, cobalt, and chrome, then the conditions used for the high-speed bench lathe would be more applicable.

Equipment and Measurement Methods

Vacuum System Design and Measurement Methods

Vacuum System Design--Two general types of vacuum systems are used today for laboratory vacuum systems. The first type is a lower static vacuum pressure system using a "squirrel cage" type vacuum source similar to the type used in exhaust hoods. The second type is a multistage turbine type system which can generate higher static vacuum pressures. For this evaluation, a 3 horsepower turbine system was obtained on loan from the U.S. Turbine Co., 1099 N. Cuyamaca St., El Cajon, CA 92020. According to our measurements, this turbine developed a static vacuum pressure of up to 3.65 in. Hg (49.6 in. H_2O). The lower vacuum pressure system was represented by connecting the piping to the exhaust hood in our dental laboratory. The system achieved a static vacuum pressure of up to 0.30 in. Hg (4.1 in. H_2O).

To use either system, the two vacuum sources were connected in series by connecting the exhaust outlet of the turbine system to the inlet opening of the exhaust fan by means of a 6.35-cm (2 1/2 in.) portion of polyvinyl chloride (PVC) pipe. The connecting method allowed the exhausting of the turbine outside the measurement area through the exhaust fan ducting. It also allowed us to use the exhaust hood fan as the vacuum source by turning off the turbine and pulling a vacuum through the same series of branch pipes, through the turbine and the exhaust hood inlet. Although this added a great deal more friction loss than is desirable for the exhaust fan vacuum source, it did not affect our measurements which were all made on the upstream side of the turbine. The turbine system connected to the exhaust fan in the PVC pipe is shown in Figure 2.

The vacuum system design layout including the location of the ports used for the vacuum attachments is shown in Figure 3. Ports #1 - #5 on the diagram are listed with a description of the type of port used and the cross-sectional area of the branch pipe feeding the port:

Port No.	Port Description	Port cross-sectional area m^2 (ft^2)
1	Open port ID = 6.17 cm (2.43 in.)	0.0030 (0.0322)
2	Open port ID = 4.01 cm (1.58 in.)	0.0013 (0.0136)
3	Open port ID = 3.43 cm (1.35 in.)	0.0009 (0.00994)
4	Drawer port = 2.41 cm x 19.30 cm (0.95 in. x 7.6 in.)	0.0047 (0.0501)
5	Open Port ID = 7.62 cm (3.00 in.)	0.0046 (0.0491)

The drawer suction port used as port #4 was part of a laboratory bench obtained from Coe Laboratories, Inc (Coe Laboratories Inc, 3737 W. 127th St., Chicago, IL 60658). The opening of the drawer suction port was 7.62-cm (3 in.) diameter giving it a cross-sectional area of 0.0046 m^2 (0.0491 ft^2). Other vacuum attachments such as the fishmouth attachment and built-in attachment for the high-speed lathe were connected to the other ports through PVC piping or flexible tubing.

A spring-loaded butterfly valve (Fig. 2) was installed just before port #5 to allow adjustment of the total system flow. The valve was placed in the full open or full closed positions, but in some instances it was set to a partially open position to fine tune the total flow to a given port.

Figures 4 and 5 show the vacuum attachments used in the study. The drawer vacuum attachment (Fig. 5B) was obtained on loan from Coe Laboratories and installed by manufacturer's instructions to the main 7.62-cm (3-in.) branch pipe leading to the vacuum source. The fishmouth vacuum attachment (Fig. 4C) is a standard item found in most USAF dental laboratories. The overhead vacuum attachment (Fig. 5A) was fabricated by MSgt Callison of DIS for this study using a typical laboratory light and flexible tubing from a commercial shop vacuum. The attachment was included to see if an overhead vacuum source incorporated directly over the technician's work area would offer any advantages over the more traditional horizontal (fishmouth) and under the work (drawer) type attachments. The built-in attachment on the Ticonium Hi Speed Lathe (Ticonium Co, P.O. Box 350, Albany, NY 12201) is shown in Figure 4A.

Measurement Methods--We took four measurements of the vacuum system:

- Capture velocity in feet/minute measurement to determine the effectiveness of the vacuum system at the location where it needs to be effective - where the grinding operation occurs (Fig. 6).

- Centerline velocity in feet/minute measurement to determine if the air in the duct system was moving quickly enough to prevent the particles captured by the system from dropping out of the air stream in the duct.

- Total air flow through a specific port and total air flow through the main branch line measurement; this was calculated by the following formula:

$$Q = 0.9 \times V \times Acs \quad \text{where } Q = \text{flow in ft}^3\text{/min}$$
$$V = \text{centerline velocity in ft/min}$$
$$Acs = \text{Cross-sectional area in ft}^2$$

All centerline velocity measurements used in the calculation were made 10 diameters from the end of the open port by the testing methods for vacuum systems recommended in the Industrial Ventilation Handbook (4, p. 93).

- The static pressure (in. Hg) measurement gives an indication of the total energy potential available from the vacuum source and an estimation of the friction losses in the system. Static pressure measurements were made 3 diameters away from the end of the open port by the testing methods recommended in the Industrial Ventilation Handbook (4, p. 93).

All capture velocity measurements were made at distances from the open duct of the vacuum attachment where the laboratory technician would reasonably and comfortably perform the indicated procedures. Where there was a question, the capture velocities were made at different distances to determine the velocity profile surrounding the vacuum attachment.

All velocity measurements were made with a Sierra hot wire anemometer (Sierra Instruments Inc., P.O. Box 909, Carmel Valley, CA 93924) (Fig. 7). The measurements were made at points A, B, C, D, and E as indicated in Figure 3. Measurements were made twice to ensure repeatability. The duct velocities were then used to calculate the total air flow in that duct.

All static pressure measurements were made with a Wallace and Tiernan pressure gauge (Fig. 8) (Wallace and Tiernan, Penwalt Corp, 25 Main St, Belleville, NJ 07109). The measurements were taken at points A, B, C, D, and E as indicated in Figure 3. These measurements were taken to allow an estimation of the total energy potential of the vacuum source. We did not attempt to calculate the friction losses for this system design.

These measurements of the vacuum system allowed the comparison of the low vacuum pressure exhaust fan to the higher vacuum pressure turbine for similar conditions. These measurements also allowed the evaluators to precisely set the vacuum system for the capture velocity desired in the air sampling portion of the evaluation. Table 7 shows the results of the vacuum system performance for various open port combinations.

Air Sampling Methods

The final determination of the effectiveness of the vacuum system is its ability to capture enough of the hazardous particles and dust to keep the airborne levels of these substances below the permissible exposure limits. This portion of the evaluation correlated the airborne concentrations of the potential hazards with the vacuum system parameters of capture velocity and total flow through the vacuum attachment.

Table 6 lists the specific operations conducted for each type of laboratory procedure and the vacuum settings for each operation. In each case, the piece of equipment (lathe or handengine) was clamped in the specified position to eliminate any movement with respect to the vacuum source. The vacuum source was turned on and the system tuned to achieve the desired capture velocity. The total flow through the port required to achieve the capture velocity was calculated. The specific grinding operation was then performed and the materials and instruments used were weighed at each step to determine the amount of material lost. Figures 4 and 5 show the equipment setup. Figure 9 shows the determination of capture velocity and centerline velocity. An experienced laboratory technician performed each of the procedures and each operation was timed.

Personnel (USAFOEHL/ECH) performed the air-sampling measurements in the following manner: Samples of air were collected from the breathing zone of the technician (Fig. 10) during the prescribed operations using a variable flow DuPont model Alpha-1 sample pump (Fig. 11). Nominal flow for all samples was 1.5 L/min through particulate filters.

Metal samples were collected on 0.8-µm pore-size 37-mm mixed cellulose ester (MCE) filters. Analysis was performed using National Institute of Occupational Safety and Health (NIOSH) Method 7300, Inductively Coupled Argon Plasma Atomic Emission Spectroscopy.

Dust samples were collected on 0.8-μm pore-size 37-mm match weighted MCE filters. Analysis was performed by weighing the filters.

Crystalline silica samples were collected on 10.8-μm pore-size 37-mm MCE filters. Analysis was performed using NIOSH Method 7501, X-Ray Powder Diffraction.

Table 8 gives the results of the measurements of the performance of the various vacuum attachments in terms of capture velocity vs. distance from the port inlet for the given flow rates. Note the large variations in the capture velocity profiles for the different attachments. The fishmouth maintains the largest capture velocity for the largest distance due to its confined design for the first 15.24 cm (6 in.). The drawer suction and the overhead suction design had comparable capture velocity vs. distance profiles. The comparison is to be expected since they both represent open port systems and only the orientation of the vacuum inlet is different. Since the ticonium vacuum attachment has a fixed distance from the vacuum inlet to the grinding surface, no capture velocity vs. distance measurements were made. A measurement of the capture velocity at different total inlet flows is listed in Table 8.

The effect of these different performance factors on the ability of the attachment to capture hazardous particles was determined in the next portion of the evaluation.

Results

Air Sampling Data

The results of the air sampling data for each of the test conditions are shown in Tables 9, 10, and 11. As a baseline, all hazardous grinding operation conditions chosen were first run with no vacuum system to obtain a baseline level except for the slow-speed bench lathe where we felt that the electric laboratory handengine with its higher speed would create a greater hazard for similar grinding operations.

In some respects the results were surprising; it appears that the slow-speed bench lathe creates a greater dust hazard than the handengine based on the results from the samples taken for the same vacuum attachment at 18.29 m (60 ft)/min capture velocity. The results indicated there was no silica hazard from grinding porcelain for the worst case condition which was chosen. The results of the metal screen for no vacuum indicate that beryllium is not the grinding hazard one would expect. Nickel and chromium were the only metal hazards which exceeded the permissible exposure limits for this condition. The results showed that there was clearly a dust hazard if no vacuum is used when keying casts and trimming dies.

In all cases the low vacuum system provided enough total flow through the vacuum port chosen to keep the amount of the hazardous substance (metals, silica or dust) well below the permissible exposure limits. A capture velocity of 18.29 m (60 ft)/min with a total flow of 0.85 m^3 (30 ft^3)/min was all that was required to keep the metal hazards from ticonium grinding below a detectable level (1/10th of the TLV) for the high-speed ticonium lathe with a

built-in attachment. A capture velocity of 18.29 m (60 ft)/min with a total port flow of 1.25 m^3 (44 f^3)/min through the fishmouth attachment was sufficient to keep the dust levels at one-half the TLV and thus below the air force action levels. Capture velocities as low as 10.67 to 15.24 m (35 to 50 ft)/min with a total flow as little as 0.57 m^3 (20 ft^3)/min kept the dust levels below the detection limit for the handengine when using the overhead attachment or drawer attachment.

DISCUSSION

Laboratory Grinding Hazards

The information provided on the Material Safety Data Sheets (MSDS) was disappointing for the most part. The information seemed to indicate a minimal attempt by the manufacturers to comply with the letter of the law in the easiest manner. In some instances the delay in the receipt of the MSDS gave the impression that the manufacturer was generating the document following the request rather than having the information readily available. The misspelling and inaccurate information on some of the MSDS seemed to indicate that the individual filling out the form was less than familiar with the subject. Despite their drawbacks, however, the MSDS still represents a simple method of obtaining valuable information about the materials that are used daily in a dental laboratory. The data sheets must be provided by the manufacturer upon request. For those individuals interested primarily in gold alloys and their alternatives currently in use, we found the two volumes by Dr Naylor (3, 4) to be invaluable.

Based upon this study, the primary hazards during grinding operations in the dental laboratory are clearly the dust generated when keying casts or trimming dies (cutting on gypsum) and the metal dust from grinding on partial denture frameworks. The air sampling levels for silica when grinding porcelain were below detectable limits, because pure silica makes up only about 2-3% of the porcelain. The main constituents are silicon dioxide and silicon carbide which have no established TLV or are treated as dust. Since the major components of crown and bridge alloys with a high gold content also have no established TLVs, it appears that they too can be treated primarily as a dust hazard. The exception to this is some of the low gold content alloys used for Maryland bridges.

The information should simplify the job of the BEE in deciding to perform air sampling in a dental laboratory. In small and medium base laboratories where high gold content alloys are primarily used, the only sampling needed is for total dust and respiratory dust. In area dental laboratories where partial denture frameworks are finished all day long or in laboratories which grind frequently on alloys with high nickel, chromium, and cobalt percentages, then a metal screen should be performed. The metal screen should include a test for beryllium, but based on this work it appears that the level of beryllium in these metals is so low that it does not constitute the primary hazard during grinding operations. Other metals such as nickel, chromium, and cobalt would present a greater hazard potential during dental laboratory grinding procedures.

Vacuum System Performance Requirements

The performance parameters required of a laboratory vacuum system depend to a great extent upon the type of laboratory and thus the materials used in the grinding operations. Based upon this study, the following requirements are recommended as sufficient to keep air quality in the dental laboratory at acceptable levels. These requirements are based upon the general types of equipment noted:

1. High-speed bench lathe with built-in vacuum attachment:

   - Capture Velocity - 182.9 m (60 ft)/min at grinding surface
   - Total Flow through the vacuum port = 0.57-0.71 m^3 (20-25 ft^3)/min
   - Based upon keeping the metals (nickel, chromium, cobalt, and beryllium) air concentrations below ACGIH and AFOSH standards.

2. Slow-speed bench lathe using fishmouth attachment:

   - Capture Velocity = 18.29 m (60 ft)/min at end of attachment
   - Total flow through the vacuum port = 1.13-1.27 m^3 (40-45 ft^3)/min
   - Based upon keeping dust air concentrations below ACGIH and AFOSH standards.

3. Laboratory electric handengine/air-driven handpiece:

   a. Using fishmouth attachment -

   - Capture velocity = 13.72 m (45 ft)/min at end of attachment
   - Total flow through vacuum port = 0.85 m^3 (30 ft^3)/min
   - Based upon keeping dust air concentrations below ACGIH and AFOSH standards

Note: Since the fishmouth attachment can be used with either the slow-speed lathe or handengine, a port designed to accept a fishmouth should be designed for 1.13-1.27 m^3 (40-45 ft^3)/min and a capture velocity of 18.29 m (60 ft)/min to accommodate either.

   b. Using drawer attachment:

   - Capture velocity = 30.48 m (100 ft)/min at 6.35 cm (2.5 in.) from opening
   - Total flow through the port = 0.57 m^3 (20 ft^3)/min
   - Based upon keeping dust air concentrations below ACGIH and AFOSH standards.

   c. Using overhead attachment:

   - Capture velocity - 10.67 m (35 ft)/min at 10.16 cm (4.0 in.) from opening
   - Total flow through the port = 0.57 m^3 (20 ft^3)/min
   - Based upon keeping dust air concentrations below ACGIH and AFOSH standards.

4. Stand-up equipment - size based upon manufacturer's requirements:

The requirements for the high-speed bench lathe only exist in an area dental laboratory where partial denture frameworks are being finished all day long. Based upon the results of our real-time study with no vacuum, only the values of chromium and nickel exceeded their allowable limit. This finding was based upon continuous grinding on frameworks. Thus, the potential hazard from the occasional adjustment and polishing of a framework in a smaller laboratory appears to be minimal.

The requirements for the other attachments are based upon controlling the dust hazard when grinding upon gypsum products such as when keying dies. The most inefficient vacuum attachment for this operation is the fishmouth but since that is the only attachment which will accommodate a slow-speed lathe, the total flow through the vacuum port to which a fishmouth can be attached must be sized to the 1.13 m^3 (40 ft^3)/min requirement. For ports designed for drawer or overhead type attachments for use with laboratory handengines only 0.57 m^3 (20 ft^3) are needed. Total flow rather than strictly capture velocity appears to be the ultimate requirements for the vacuum attachments. The overhead attachment had a lower capture velocity than the drawer attachment at the point where the grinding operation took place primarily because one could get closer to the drawer attachment inlet than the overhead attachment despite their identical capture velocity profiles. However, despite the difference in capture velocity measurements, the two attachments both kept the air concentrations of the dust at an acceptable level with only 0.57 m^3 (20 ft^3)/min. The placement of the overhead attachment between the work and the breathing zone greatly aided its ability to pick up the dust and offset the inability to get closer to the vacuum inlet port where the capture velocity was greater. The drawer attachment or the overhead type attachment would be preferable to the fishmouth since they are much more efficient at removing the hazardous particles from the breathing zone. The laboratory technician preferred the overhead type because he could position the light and suction in the position he deemed most comfortable for the particular procedure he was performing. This position varied depending on whether he was keying casts or trimming dies.

Note that the low vacuum system could provide the required total flow for each type of attachment. The only area in which the low vacuum system was deficient was that it could not keep the duct velocity about 1066.8 m (3500 ft)/min for all portions of our piping system. The system did, however, have the energy capable of achieving a duct velocity in excess of 1066.8 m (3500 ft)/min in the small diameter ducts. This result indicates that the problem with the system was a total flow problem rather than a problem with vacuum pressure. The decision on the type of vacuum source would then depend upon the total flow required of the system and the location of the vacuum source in relation to laboratory and thus the friction losses of the piping system. We feel that a minimum duct velocity of 1066.8 m (3500 ft)/min should be specified but that the required vacuum pressure not be specified since it would depend strongly upon the vacuum system design.

The most important aspect of the vacuum system in terms of its performance is the proper balancing of the system so that the required flow is achieved for each port regardless of the number of other ports that are open.

Requiring the minimum flows previously listed for each type of port when all ports are open should adequately size the total flow through the system. It is important that this minimum flow can be achieved even for the port at the farthest end of the piping system from the vacuum source to ensure that the individual working at that port is properly protected from airborne particulate hazards. Proper balancing is important on the other end also to ensure that the noise hazard from the vacuum system does not exceed required standards in the event that only one or two ports are open. The noise created by moving air is proportional to the square of its velocity so that if a system is improperly balanced and a much higher flow (and thus air velocity) is created through a given port when other ports are closed, there is a high potential to produce a noise hazard. The same situation can result if the same quantity of air flow is "forced" through a smaller diameter inlet opening by means of increased vacuum pressure, thus increasing the air velocity and noise hazard. The resulting high pitched whine can be annoying as well as potentially hazardous. If the vacuum system noise level is below ACGIH standards, the combination of the high pitch whine of the high vacuum pressure system and the grinding procedure may create a potential noise hazard requiring hearing protection. For these reasons, we recommend that all balancing mechanisms such as piping constrictions or valves be placed below the level of the workbench prior to the vacuum port inlet to reduce the noise potential. The butterfly valve with spring appeared to be a reasonable method to balance the flow to the ports since it could be adjusted to open automatically if other ports were closed and a higher vacuum pressure in the duct occurred. A similar valve at the end of each branch line could ensure a constant flow of air to the vacuum source and provide a means of balancing the system. This method also ensures that the minimum duct velocity is maintained in all portions of the piping system.

When designing a vacuum system, the incorporation of a vacuum gauge in the main branch line can be a useful item for checking the system. The gauge not only gives an indication of the energy potential of a new system, but it provides a quick method of checking deterioration of the vacuum system over a period of time. The gauge can be invaluable in helping to troubleshoot system performance in the event that the vacuum system does not seem to be performing properly.

The previous discussion has dealt primarily with requirements to be used when designing or procuring a vacuum system, but they also apply when measuring the vacuum system for proper performance. As a quick check, the BEE can measure the capture velocity previously listed for a given attachment and operation or measure the total flow through that port. This quick check is not a replacement for air sampling measurements, but if baseline air sampling measurements were made and correlated to the capture velocity and total flow measurements of that system, then it would appear reasonable that if the laboratory operations had not changed and the vacuum system parameters had not changed then the air quality should not have changed substantially. To ensure that the system, as a whole, is operating properly, measure the duct velocities in the main lines and branch lines to ensure they exceed the recommended 1066.8 m (3500 ft)/min. Another quick check is to measure the present line static pressure with all ports closed and all ports open, and compare the readings to the readings obtained when the system was new.

The major human variable in the system is the laboratory technician. His primary concern is to produce a fine quality restoration, and as a result, he often concentrates on his efforts to the extent that he pulls or moves the work away from the vacuum source when using the handpiece or handengine. It is important for the technician to remember that some grinding operations are inherently more hazardous than others and to exercise extra caution when performing those procedures. The prime operations of concern are those that produce a large amount of dust or particulate matter in a short time. The two major culprits are: (1) grinding on gypsum products such as stone or plaster (see Fig. 12), and (2) cutting sprues and rough grinding of metal. During these procedures, the technician should ensure that the work is held as close to the vacuum inlet as possible to maximize the effectiveness of the vacuum system. An excellent added precautionary measure is to wear a NIOSH approved dust respirator during grinding procedures. Check with your base BEE for information on different styles and types of respirators or contact the Dental Investigation Service.

CONCLUSIONS

The primary hazards from grinding procedures in the dental laboratory are: (1) dust from keying casts and trimming dies, and (2) hazardous metal particles from partial denture frameworks and other chromium-, cobalt-, or nickel-containing alloys. High gold content alloys can be treated as a dust hazard since their major constituents have permissible exposure levels higher than respiratory dust.

When designing a laboratory vacuum system, the following parameters are required for each type of vacuum port listed:

(1) High-speed lathe with built-in attachment for metal grinding--requires total flow of 0.57-0.71 m^3 (20-25 ft^3)/min to achieve a capture velocity of 18.29 m (60 ft)/min based on keeping metal particulate concentrations well below permissible exposure limits.

(2) Fishmouth attachment--requires total flow of 1.13-1.27 m^3 (40-45 ft^3/min to achieve a capture velocity of 18.29 m (60 ft)/min at the end of the fishmouth for use with slow-speed bench lathe. Based to keeping respirable dust concentration well below permissible exposure level of 5 mg/m^3.

(3) Drawer attachment-- requires a total flow of 0.57 m^3 (20 ft^3)/min to achieve a capture velocity of 30.48 m (100 ft)/min 6.35 cm (2.5 in.) above drawer inlet for use with laboratory handpieces. Based upon keeping the respirable dust concentrations well below the permissible exposure level of 5 mg/m^3.

(4) Overhead attachment--requires a total flow of 0.57 m^3 (20 ft^3) to achieve a capture velocity of 10.67 m (35 ft)/min 10.16 cm (4.0 in.) below inlet for use with laboratory handpieces. Based upon keeping the respirable dust concentrations well below the permissible exposure level of 5 mg/m^3.

The total system flow should be designed to accommodate the sum of the required flows for each type of port and attachment required. Use factors

can be applied to the total flow requirement. In addition, a requirement that the duct velocity in the branch ducts and main duct shall be at least 1066.8 m (3500 ft)/min should be included. Specification of a required vacuum pressure should not be included. The required vacuum pressure will be highly dependent upon the system design, pipe diameters, location of the vacuum source, and other factors which affect the function losses of the system.

A method of balancing the system for different open port combinations is essential. Use of an automatically adjusting relief valve at the end of each branch line is an excellent method. Any balancing method which uses a restrictive orifice should be placed below the bench top and designed so that the noise level does not exceed AFOSH standards (84 dBA) when only a single port is open.

When a base BEE approaches the task of doing a baseline survey, he should determine the grinding procedures performed in that base dental laboratory. Table 4 can provide a good initial list to begin this assessment. It appears that a total dust and respiratory dust should be the only air sampling required in most laboratories. For area dental laboratories and other laboratories where high chromium, cobalt, or nickel alloys are used frequently a metals screen should be accomplished. For annual reviews a simple check to ensure that the vacuum system performance has not changed and meets the total flows and capture velocities previously listed should be sufficient. The tables in this report can provide valuable information on the types of grinding operations performed in a dental laboratory and the potential hazards. If you have further questions, you can contact personnel at the Occupational Environmental Health Laboratory or Dental Investigation Service.

REFERENCES

1. Department of the Air Force, "Dental Laboratory Technology," AF Manual 162-6, Nov 1982.

2. American Conference of Governmental Industrial Hygienists, "Threshold Limit Values and Biological Exposure Indices for 1985-1986," ACGIH, Cincinnati, Ohio, 1986.

3. Naylor, W.P., and J. M. Young, Non-Gold Base Dental Casting Alloys: Vol I Alternatives to Type III Gold. USAFSAM-TR-84-49, Apr 1985.

4. Naylor. W.P. Non-Gold Base Dental Casting Alloys: Vol II Porcelain-Fused-to-Metal Alloys. USAFSAM-TR-86-5, Aug 1986.

5. American Conference of Governmental Industrial Hygienists, Industrial Ventilation, A Manual of Recommended Practice. Committee on Industrial Ventilation, Lansing, Michigan, 1982.

Material Safety Data Sheet
May be used to comply with
OSHA's Hazard Communication Standard,
29 CFR 1910.1200. Standard must be
consulted for specific requirements.

U.S. Department of Labor
Occupational Safety and Health Administration
(Non-Mandatory Form)
Form Approved
OMB No. 1218-0072

IDENTITY (*As Used on Label and List*)

Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.

Section I

Manufacturer's Name	Emergency Telephone Number
Address (*Number, Street, City, State, and ZIP Code*)	Telephone Number for Information
	Date Prepared
	Signature of Preparer (*optional*)

Section II — Hazardous Ingredients/Identity Information

Hazardous Components (Specific Chemical Identity; Common Name(s))	OSHA PEL	ACGIH TLV	Other Limits Recommended	% (optional)

Section III — Physical/Chemical Characteristics

Boiling Point		Specific Gravity (H_2O = 1)	
Vapor Pressure (mm Hg.)		Melting Point	
Vapor Density (AIR = 1)		Evaporation Rate (Butyl Acetate = 1)	

Solubility in Water

Appearance and Odor

Section IV — Fire and Explosion Hazard Data

Flash Point (Method Used)	Flammable Limits	LEL	UEL

Extinguishing Media

Special Fire Fighting Procedures

Unusual Fire and Explosion Hazards

(Reproduce locally) OSHA 174, Sept. 1985

Section V — Reactivity Data

Stability	Unstable		Conditions to Avoid
	Stable		

Incompatibility (*Materials to Avoid*)

Hazardous Decomposition or Byproducts

Hazardous Polymerization	May Occur		Conditions to Avoid
	Will Not Occur		

Section VI — Health Hazard Data

Route(s) of Entry: Inhalation? Skin? Ingestion?

Health Hazards (*Acute and Chronic*)

Carcinogenicity: NTP? IARC Monographs? OSHA Regulated?

Signs and Symptoms of Exposure

Medical Conditions Generally Aggravated by Exposure

Emergency and First Aid Procedures

Section VII — Precautions for Safe Handling and Use

Steps to Be Taken in Case Material Is Released or Spilled

Waste Disposal Method

Precautions to Be Taken in Handling and Storing

Other Precautions

Section VIII — Control Measures

Respiratory Protection (*Specify Type*)

Ventilation	Local Exhaust	Special
	Mechanical (General)	Other

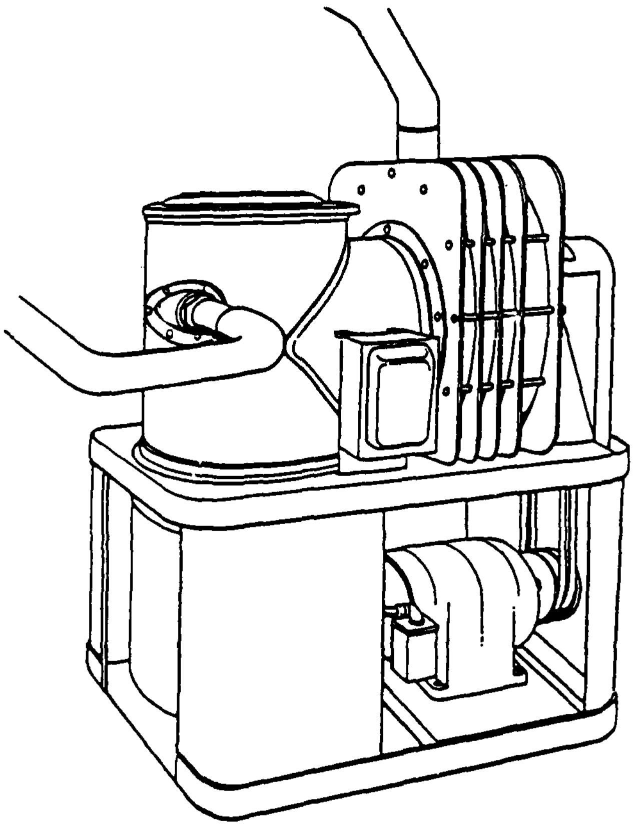
Protective Gloves	Eye Protection

Other Protective Clothing or Equipment

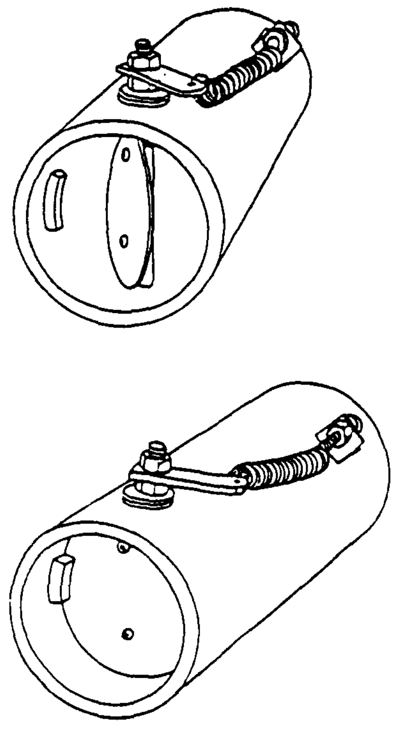
Work/Hygienic Practices

Page 2

Figure 1. Material Safety Data Sheet.



A: Turbo exhauster was used to generate high vacuum pressures while providing the required flow rates.



B: The butterfly valve was used to feed air to the turbine when all other parts were closed off.

Figure 2. Turbine vacuum source and butterfly valve.

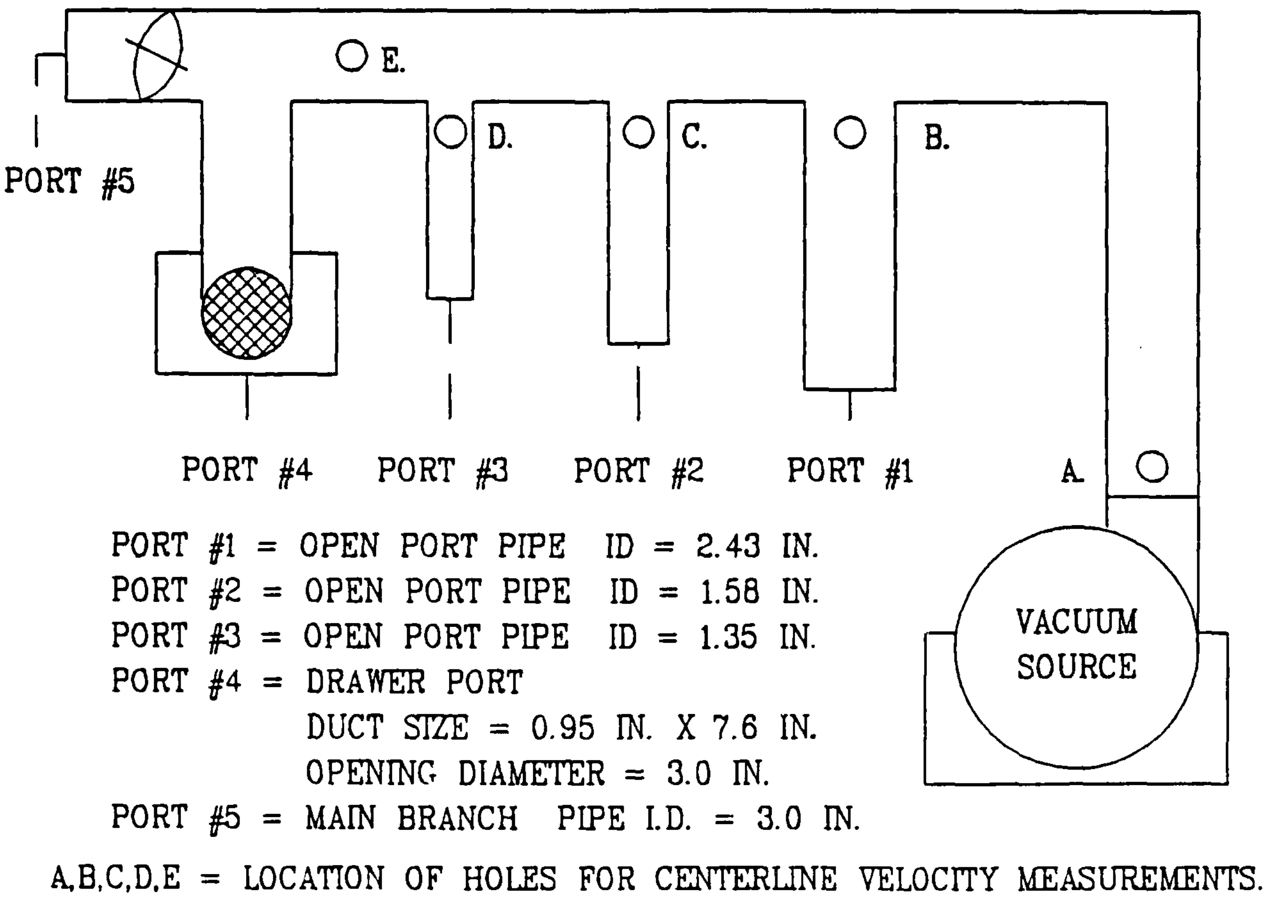
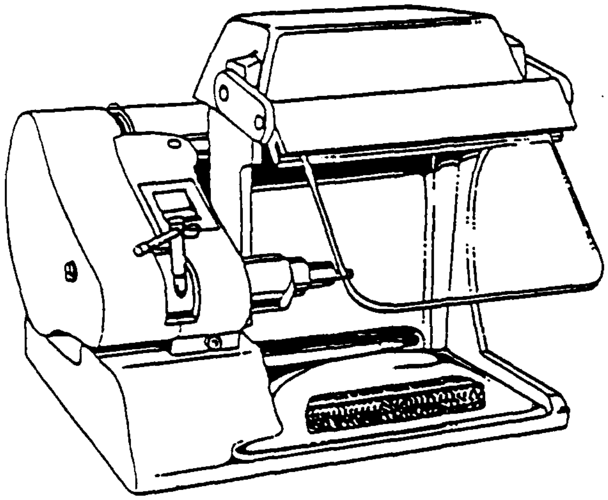
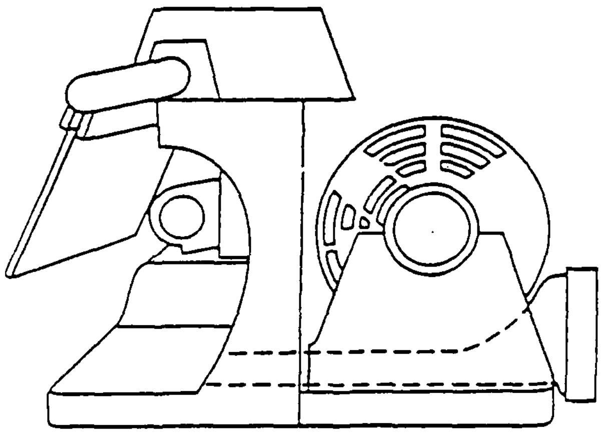


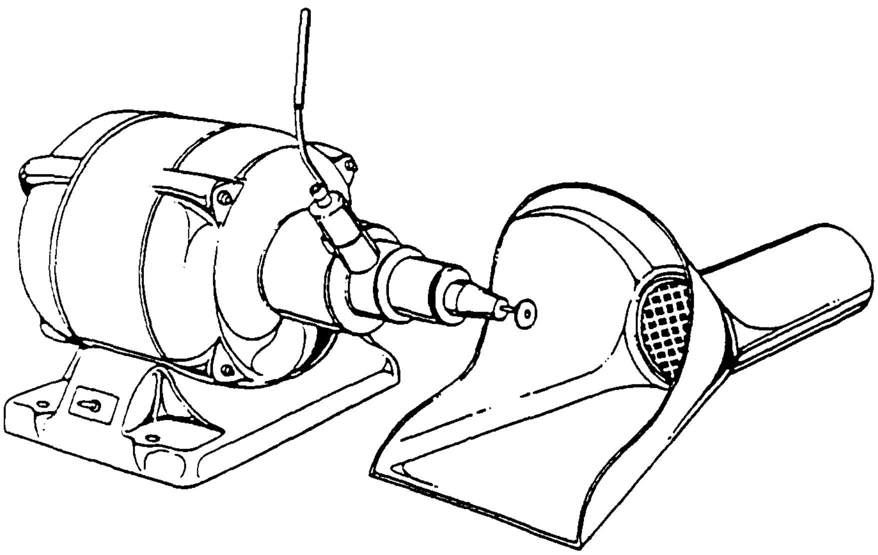
Figure 3. Vacuum piping system.



A: The screen filter in this high-speed lathe reduced vacuum flow as it became impacted with grinding residue.

B: Cross-sectional view of high-speed lathe shows the rapid reduction of the vacuum duct.

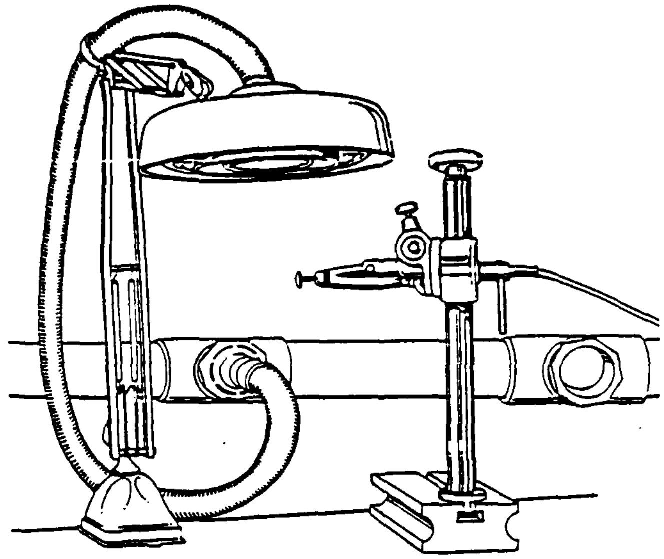


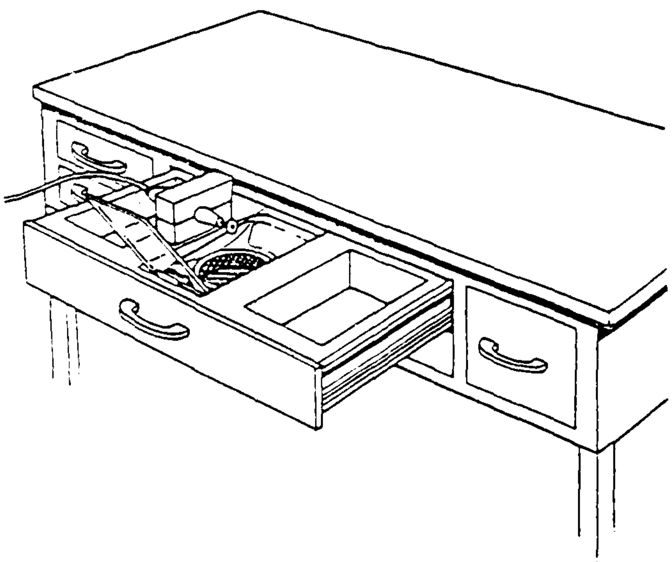


C: The bench lathe was used with a standard fish-mouth vacuum system adapter.

Figure 4. Test setup: high-speed lathe and bench lathe (with fishmouth)

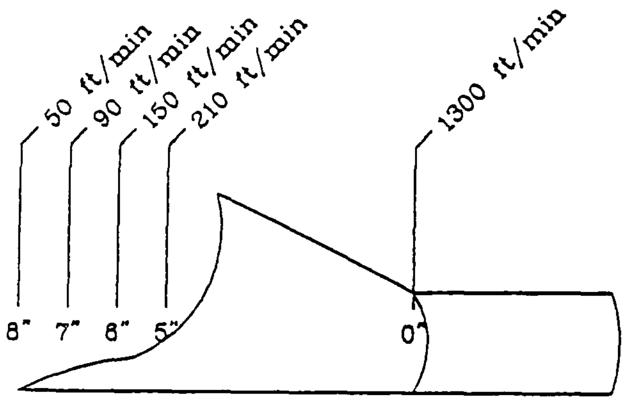
A: Overhead suction was fabricated for this test using a standard bench light with magnification lens. The lens was removed and the vacuum source was drawn through the opening using 1-½ flexible hose and a special adapter fabricated for this test. This device provided adequate suction with good task lighting.





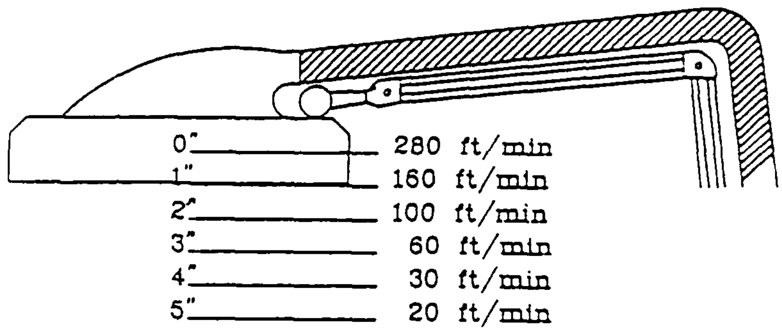
B: Work bench drawer suction test setup.

Figure 5. Test setup: overhead and drawer suction with handpiece.



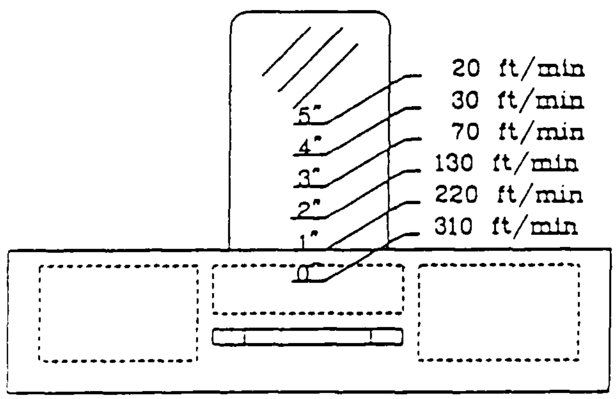
A: Fishmouth

Total flow = 40 ft^3/min



B: Overhead

Total flow = 20 ft^3/min



C: Drawer

Total flow = 20 ft^3/min

Figure 6. Test setup: determining position for optimum capture velocity. (Note: capture velocity drops off dramatically as you move away from adapter opening.)

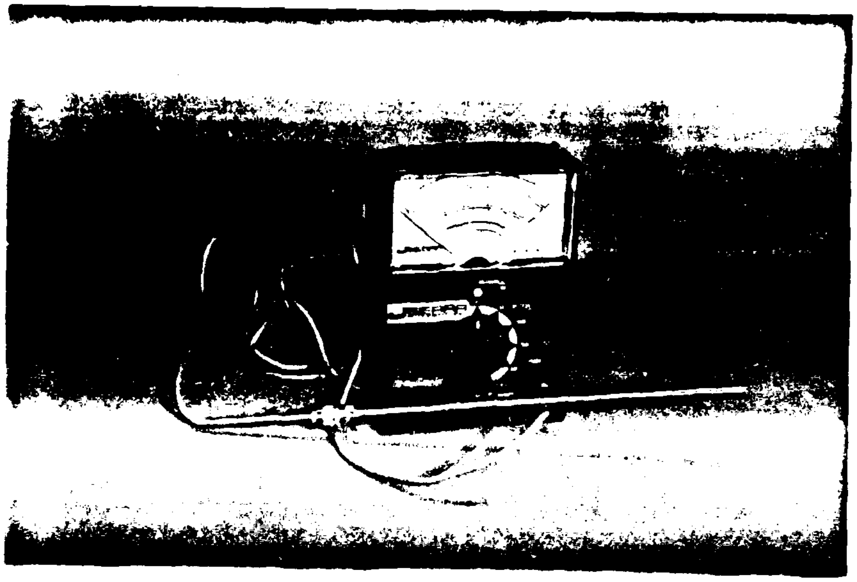


Figure 7. Sierra hot wire anemometer.

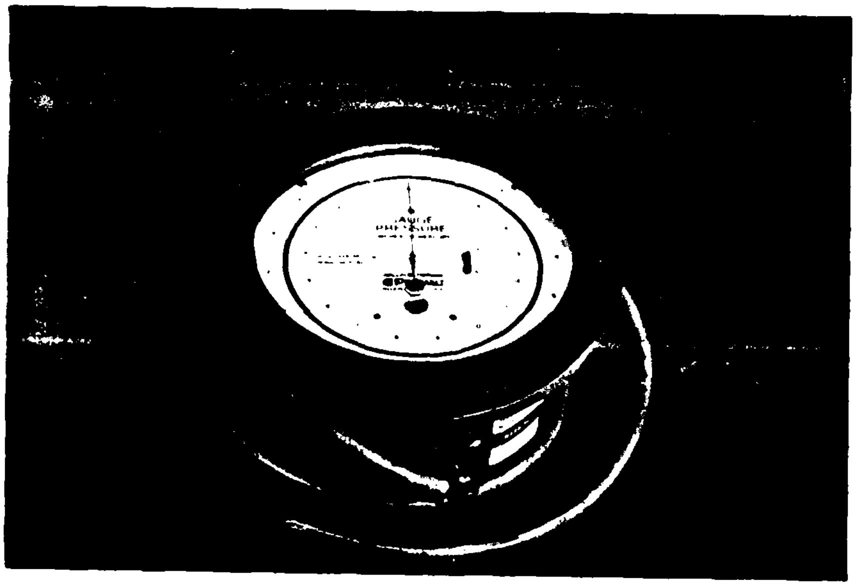
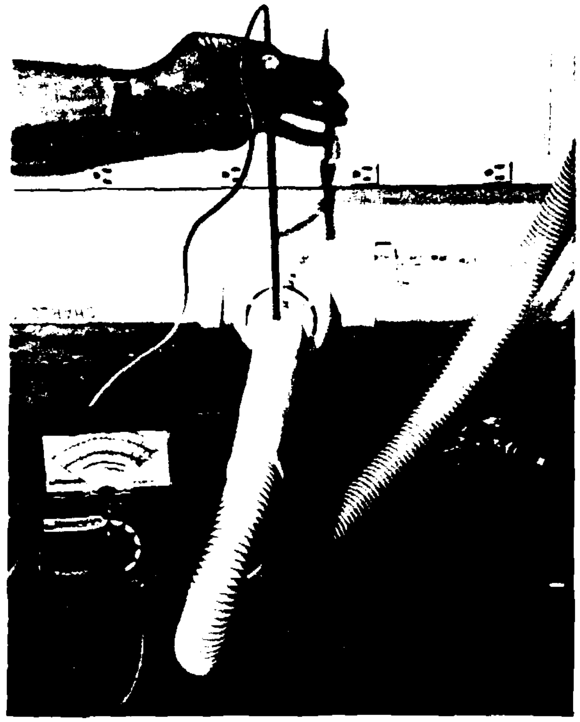
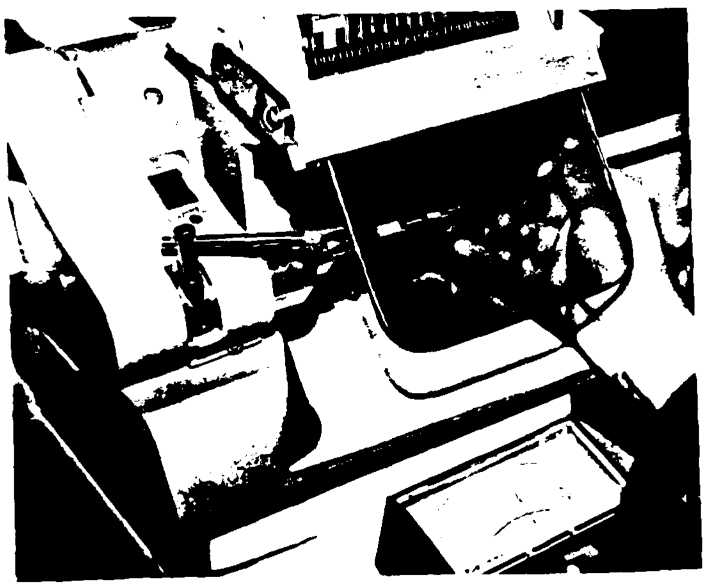


Figure 8. Vacuum pressure gauge.

A: Measuring centerline velocity using the hot wire anemometer.





B: Measuring capture velocity using the hot wire anemometer.

Figure 9. Test setup: measuring centerline velocity and capture velocity.

Figure 10. Technician wearing alpha-1 sample pump. (Note: filter is located in breathing zone of operator.)

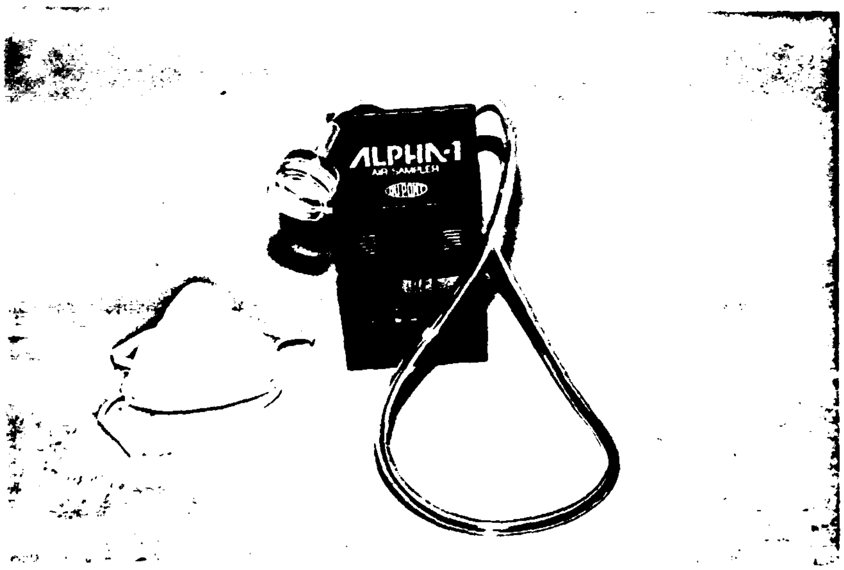


Figure 11. Alpha-1 sample pump and filter mask.

Figure 12. Dust produced when grinding gypsum floats freely through the breathing zone.

TABLE 1. LABORATORY MATERIALS AND INSTRUMENTS SUBJECTED TO GRINDING PROCEDURES

Product class	Brand name	Manufacturer
Alloy, ceramic	Olympia	Jelenko
Alloy, ceramic alt.	Cobond	Dentsply
Alloy, ceramic alt.	Supra-AP	Jeneric
Alloy, ceramic alt.	Biobond II	Dentsply
Alloy, ceramic alt.	PRM-88	Jelenko
Alloy, ceramic alt.	Jel-5	Jelenko
Alloy, ceramic alt.	Naturelle	Jeneric
Alloy, partial dent.	Premium 100	Ticonium
Alloy, partial dent.	Vitallium Alloy	Austenal Dental
Alloy, type II	Rx B, NSN 6520-00-145-0350	Jeneric
Alloy, type III	RAJA	Jelenko
Alloy, type III	Rx C, NSN 6520-00-145-0176	Jeneric
Alloy, type III	Cameo	Jelenko
Alloy, type III alt.	Light Cast B	Williams Gold
Alloy, type III alt.	Novarex	Jeneric
Alloy, type III alt.	Midas	Jelenko
Alloy, type III alt.	Albacast	Jelenko
Alloy, type III alt.	PMW	Jeneric
Alloy, type IV	Rx IV, NSN 6520-00-145-0349	Jeneric
Denture base	Lucitone Powder	Dentsply York
Denture base	Lucitone Liquid	Dentsply
Denture base	Triad	Dentsply
Denture base	Lucitone 199 Powder	Dentsply
Denture reline mat.	Tru Soft	Harry J. Bosworth

Grinding stone	Green Lathe Wheel	Ticonium
Grinding stone	Separating Discs	Ticonium
Grinding stone	Ruby Points	Ticonium
Grinding stone	Acrylic Trimmer	Ticonium
Grinding wheels	Rubber Wheels	Ticonium
Gypsum	Silky Rock	Whip Mix
Gypsum	Die-Keen	Modern Materials
Gypsum	Plaster	Modern Materials
Gypsum	Model Plaster	Whip Mix
Polishing compound	BBC Buffing Compound	Jelenko
Polishing compound	Ti-Hi	Ticonium
Polishing compound	Pumice	Whip Mix
Polishing compound	Pumice	Modern Materials
Polishing compound	Mirobuff Polish	Jelenko
Polishing compound	Scratch-off Polish	Jelenko
Porcelain	Artis-Tech Porcelain	Jeneric
Porcelain	Biobond	Dentsply
Resin, C&B composite	Visio-Gem Pastes	ESPE Premier
Resin, C&B composite	Visio-Gem Opaque	ESPE Premier
Resin, C&B temporary	Temporary Bridge Resin Liquid	Dentsply
Tissue conditioner	Coe Comfort Liquid	Coe Laboratories
Tissue conditioner	Coe Comfort Powder	Coe Laboratories
Tissue conditioner	Lynal	Dentsply
Tray material	Formatray	Kerr
Tray material	Resin Tray Material	Plastodent
Tray material	Sure Tray	Modern Materials

TABLE 2. CONSTITUENTS OF MATERIALS AND INSTRUMENTS

Product class	Brand name (Manuf)	Constituent	Approx %
Alloy, ceramic	Olympia (Jelenko)	Gold	51.5
		Palladium	38.5
		Indium[a]	
Alloy, ceramic alt.	Cobond (Dentsply)	Cobalt[a]	65.0
		Chromium[a]	25.0
		Molybdenum[a]	5.0
Alloy, ceramic alt.	Supra-AP (Jeneric)	Palladium	82.5
		Cobalt[a]	6.5
		Gallium	7.0
		Indium[a]	4.0
Alloy, ceramic alt.	Biobond II (Dentsply)	Nickel[a]	80.0
		Chromium[a]	15.0
		Vanadium[a]	5.0
		Beryllium[a]	2.0

Table 2 -- continued

Product class	Brand name (Manuf)	Constituent	Approx %
Alloy, ceramic alt.	PTM-88 (Jelenko)	Palladium	88.0
Alloy, ceramic alt.	Jel-5 (Jelenko)	Palladium	54.0
		Silver[a]	38.5
Alloy, ceramic alt.	Naturelle (Jeneric)	Palladium	79.0
		Copper[a]	10.0
		Gallium	9.0
		Gold	2.0
Alloy, partial dent.	Premium 100 (Ticonium)	Nickel[a]	80.0
		Chromium[a]	15.0
		Molybdenum[a]	5.0
		Beryllium[a]	0.8
Alloy, partial dent.	Vitallium alloy (Austenal)	Chromium[a]	No
		Cobalt[a]	Info[c]
Alloy, type II	Rx B, NSN 6520-00-145-0350 (Jeneric)	Gold	75.0
		Silver[a]	15.0
		Palladium	3.0
		Copper[a]	6.0
		Zinc[a]	1.0
Alloy, type III	Raja (Jelenko)	Gold	58.0
		Palladium	3.5
		Silver[a]	27.0
		Copper[a]	10.5
Alloy, type III	Rx C, NSN 6520-00-145-0176 (Jeneric)	Gold	75.0
		Silver[a]	11.0
		Palladium	3.0
		Copper[a]	10.0
		Zinc[a]	1.0
Alloy, type III	Cameo (Jelenko)	Gold	52.5
		Palladium	27.0
		Silver[a]	16.0
Alloy, type III alt.	Light Cast B (Williams Gold)	Nickel[a]	68.5
		Chromium[a]	15.5
		Molybdenum[a]	14.0
		Beryllium[a]	1.6
Alloy, type III alt.	Novarex (Jeneric)	Cobalt[a]	55.0
		Chromium[a]	25.0
		Ruthenium	5.0
		Tungsten[a]	11.0

Alloy, type III alt.	Midas (Jelenko)	Gold Palladium Silver[a] Copper[a]	46.0 6.0 39.5 7.5
Alloy, type III alt.	Albacast (Jelenko)	Palladium Silver[a]	25.0 70.0
Alloy, type III alt.	PMW (Jeneric)	Silver[a] Palladium Indium[a] Zinc[a]	71.0 25.0 3.0 1.0
Alloy, type IV	Rx IV, NSN 6520-00-145-9349	Gold Silver[a] Palladium Copper[a] Zinc[a]	68.0 12.0 6.0 11.0 1.0
Denture base	Lucitone powder (Dentsply)	No hazard[b]	No Info[c]
Denture base	Lucitone liquid (Dentsply)	Methyl methacrylate[a]	100.0
Denture base	Triad (Dentsply)	No hazard[b]	No Info[c]
Denture base	Lucitone 199 powder (Dentsply)	Benzoyl peroxide[a] Cadmium sulfide[a] Titanium dioxide[a]	0.2 0.1 0.1
Denture reline mat. info	Tru Soft (Harry J. Bosworth)	No hazard[b]	No Info[c]
Grinding stone	Green lathe wheel (Ticonium)	Silicone carbide[a] Phenolic resin	No Info[c]
Grinding stone	Separating discs (Ticonium)	Aluminum oxide[a] Phenolic resin	No Info[c]
Grinding stone	Ruby points (Ticonium)	Aluminum oxide[a] Feldspar[a]	No Info[c]
Grinding stone	Acrylic trimmer (Ticonium)	Aluminum oxide[a] Feldspar[a]	No Info[c]
Grinding wheels	Rubber wheels (Ticonium)	Neoprene rubber Silicone carbide[a]	No Info[c]
Gypsum	Silky rock (Whip Mix)	Calcium sulfate Iron oxide[a]	99.0 1.0

Table 2 -- continued

Product class	Brand name (Manuf)	Constituent	Approx %
Gypsum	Die-Keen (Modern Materials)	Calcium sulfate	100.0
Gypsum	Plaster (Modern materials)	Calcium sulfate	100.0
Gypsum	Model plaster (Whip Mix)	Calcium sulfate	100.0
Polishing compound	BBC buffing compound (Jelenko)	Silica/silicone carb Triethyl amine[a]	65.0 3.0
Polishing compound	Ti-Hi (Ticonium)	Aluminum oxide[a] Calcium carbonate[a]	65.0 19.0
Polishing compound	Pumice (Whip Mix)	Silica[a] Alumina[a]	75.0 20.0
Polishing compound	Pumice (Modern Materials)	Silicone dioxide Aluminum trioxide[a] Potassium	73.0 11.0 6.0
Polishing compound	Mirrobuff polish (Jelenko)	Silica/silicone[a] carb Triethyl amine[a]	72.0 3.0
Polishing compound	Scratch-off polish (Jelenko)	Silica/silicone[a] carb Triethyl amine[a]	82.0 3.0
Porcelain	Artis-Tech Porcelain (Jeneric)	Silicone dioxide Aluminum trioxide[a]	No Info[c]
Porcelain	Biobond (Dentsply)	Silica dioxide Silica[a]	62.0 2.0
Resin, C&B composite	Visio-Gem pastes (ESPE Premier)	Bis-methacrylate Photo initiator Inorganic filler Pigments	No Info[c]
Resin, C&B composite	Visio-Gem opaque (ESPE Premier)	Methyl ethyl ketone[a] Titanium dioxide[a] Polyvinyl chloride[a]	No Info[c]
Resin, C&B temporary	Temporary bridge resin liquid (Dentsply)	Methyl methacrylate[a] Ethylene glyc dimeth[a] Phenyl salicylate Hydroquinone[a]	90.0 4.0 4.0 1.0

Tissue conditioner	Coe comfort liquid (Coe Laboratories)	Ethanol[a] Dibutyl phthalate[a]	7.0 3.0
Tissue conditioner	Coe comfort powder (Coe Laboratories)	No hazard[b]	No Info[c]
Tissue conditioner	Lynal (Dentsply)	Ethanol[a]	7.0
Tray material	Formatray (Kerr)	Methyl methacrylate[a]	98.0
Tray material	Resin tray material (Plastodent)	Methyl methacrylate[a]	99.0
Tray material	Sure tray (Modern Materials)	Methyl methacrylate[a]	99.0

[a]Indicates a substance for which a TLV has been established.

[b]Indicates manufacturer said that the item contained no hazardous constituents.

[c]Indicates manufacturer did not provide information on the percentage of the constituents.

TABLE 3. THRESHOLD LIMIT VALUES FOR CONSTITUENTS

Constituent	Threshold Limit Value (mg/m^3)
Alumina	Treat as dust
Aluminum oxide	10.0
Benzoyl peroxide	5.0
Beryllium	0.002 (suspected carcinogen)
BIS-methacrylate	None
Cadmium sulfide	0.05
Calcium sulfate	None
Calcium carbonate	Treat as dust
Chromium	0.5
Cobalt	0.05
Copper	1.0

Table 3 -- continued

Constituent	Threshold Limit Value (mg/m^3)
Dibutyl phthalate	5.0
Dust	10.0 (respirable dust = 5.0)
Ethanol	1,900 (as vapor)
Feldspar	Treat as dust
Gallium	None
Gold	None
Indium	0.1
Hydroquinone	2.0
Iron oxide	5.0
Manganese	5.0
Methyl ethyl ketone	590 (as vapor)
Methyl methacrylate	410.0 (as vapor)
Molybdenum	10.0
Neoprene rubber	None
Nickel	1.0
Palladium	None
Phenolic resin	None
Phenyl salicylate	None
Polyvinyl chloride	10.0 (possible carcinogen)
Polyvinyl acetate	30.0
Potassium	None
Ruthenium	None
Silica	0.1
Silicone carbide	Treat as dust
Silicone dioxide	None
Silver	0.1

Titanium dioxide	Treat as dust
Tungsten	5.0
Triethyl amine	40.0
Vanadium	0.05
Zinc	Treat as dust

TABLE 4. LABORATORY EQUIPMENT CATEGORIES AND TYPES OF GRINDING OPERATIONS

Grinding Operation	Materials Ground	Grinding Instruments
	High-Speed Bench Lathe	
1. Desprue, contour & polish removable partial denture framework	Partial denture alloy Type IV alloy	Separating disc Grinding stones Rubber wheels Polishing compound
2. Contour & polish denture bases	Denture base	Acrylic bur Polishing compound
	Slow-Speed Bench Lathe	
1. Polish porcelain fused to metal crown or FPD	Ceramic alloy Ceramic Alt. alloy Porcelain (C&B comp. resin)	Grinding stones Rubber points Polishing compounds
2. Polish all metal crown or FPD	Type III alloy Type III alt. alloy	Grinding stones Rubber points
3. Contour & polish denture bases	Denture base	Acrylic bur Polishing compounds
4. Contour custom trays	Tray material	Acrylic bur Grinding stones
5. Key max/man set of casts	Gypsum	Acrylic bur Grinding stones
6. Trim die	Gypsum	Round carbide bur
7. Trim immediate denture cast	Gypsum	Acrylic bur Grinding stones

Table 4.--continued

Grinding Operation	Material Ground	Grinding Instruments
	Laboratory Electric Handengine/Air-Driven Handpiece	
1. Contour and polish porcelain fused to metal crown or FPD	Ceramic alloy Ceramic alt. alloy Porcelain (C&B comp. resin)	Grinding stones Rubber points Polishing compounds
2. Contour and polish all metal crown or FPD	Type III alloy Type III alt. alloy	Grinding stones Rubber points Polishing compounds
3. Contour & polish denture bases	Denture base	Acrylic bur Polishing compounds
4. Contour custom tray	Tray material	Acrylic bur Grinding stones
5. Key max/man set of casts	Gypsum	Acrylic bur Grinding stones
6. Trim die	Gypsum	Round carbide bur
7. Trim immediate denture cast	Gypsum	Acrylic bur Grinding stones
8. Partial denture identification	Partial denture alloy	Round bur Grinding stones
	Stand-up Equipment	
1. Microblaster (for removing investment and oxides)	Crowns Bridges	Sand Aluminum oxide Glass beads
2. Shell blaster (for removing gypsum)	Dentures	Walnut Shells

TABLE 5. ESTIMATED WORST CASE CONDITIONS FOR EACH TYPE OF GRINDING OPERATION

Grinding operation description	Estimated maximum frequency per day Small lab	Medium lab	Area lab
High-Speed Bench Lathe			
Contour, smooth and polish a removable partial denture framework	0	0	6-8
Alter and polish RPD framework	2	3	0
Slow-Speed Bench Lathe			
Polish porcelain fused to metal crown	2 units	4 units	15 units
Key set of max/man casts	2 sets	8 sets	0
Trim die	3 dies	8 dies	0
Trim immediate denture cast	1 cast	1 cast	0
Trim refractory model	0	0	2 models
Laboratory Hand Engine			
Contour and polish porcelain fused to metal crown	2 units	4 units	15 units
Contour and polish all metal crown	3 units	4 units	15 units
Key set of max/man casts	2 sets	8 sets	0
Trim die	3 dies	8 dies	0
Trim immediate denture cast	1 cast	1 cast	0
Trim refractory model	0	0	2 models

Stand-up Equipment Requiring External Vacuum Source

Each piece of equipment (shell blaster or microblaster) has its own specific function and is self contained - no need to define operations.

TABLE 6. GRINDING CONDITIONS AND VACUUM SETTINGS FOR AIR SAMPLING TESTS

Grinding operation	Hazard	Vacuum attach	Dist to inlet (in.)	Capture vel. (ft/min)	Flow (ft^3/min)
		High-Speed Bench Lathe			
Contour, smooth & finish partial framework	Metals	Ticonium lathe	4.5	0	0
				60	25
				100	35
		Slow-Speed Bench Lathe			
Key 2 sets of casts	Dust	Fishmouth	8.25	60	45
		Laboratory Electric Handengine/Air Driven Handpiece			
Key 2 sets of casts and trim 2 dies	Dust	None	N/A	0	0
	Dust	Fishmouth	8.25	45	30
		Fishmouth	8.25	60	45
		Fishmouth	8.25	100	60
	Dust	Drawer	2.6	50	10
		Drawer	2.6	85	14
		Drawer	2.6	100	16
	Dust	Overhead	4.0	35	20
		Overhead	4.0	50	30
		Overhead	4.0	65	50
Contour and polish	Silica	None	N/A	0	0
		Stand-up Equipment			
No air sampling measurements made.					

TABLE 7. PERFORMANCE OF VACUUM SOURCES

Vacuum Source	Pipe dia (in.)	Static pressure (in. Hg.) (no flow)	Centerline vel. (ft/min)	Total flow (ft^3/min)
A. Vacuum source connected to 2-ft section of open pipe only - used to determine the static pressure of the vacuum source and duct velocity capability				
Hi Vacuum	3.00	3.65	4900	217
	2.43	3.65	6000	174
	1.58	3.65	8000	98
Low Vacuum	3.00	0.30	1900	84
	2.43	0.30	2600	75
	1.58	0.30	4600	56

Ports Open	Branch pipe size (in.)	Center vel. at port (ft/min)	Total flow through port (ft^3/min)	Center vel. at Pt. A (ft/min)	Total flow of system (ft^3/min)
B. Vacuum source connected to piping system per Figure 3.					
(1) Vacuum source = Hi vacuum Static pressure (no flow) = 2.45 in. Hg					
5	3.00	4700	208	4800	212
4 = Drawer x 7.6 in	0.95	4800	216	490	216
3	1.35	11,000	98	4400	194
2	1.58	11,000	135	4400	194
1	2.43	5900	171	4400	194
(2) Vacuum Source = Low Vacuum Static Pressure (no flow) = 0.15 in. Hg					
5	3.00	1380	61	1450	64
4 = Drawer x 7.6	0.95	1370	61	1500	66
3	1.35	4500	40	1480	65
2	1.58	3500	43	1480	65
1	2.43	2200	64	1700	75

TABLE 8. VACUUM ATTACHMENT PERFORMANCE

Total flow (ft^3/min)	Capture velocity (ft/min)
Ticonium Bench Lathe - measured at grinding surface = approx 12.7 cm (5 in.) from inlet.	
101	500
67	210
46	115
35	100
25	70
20	50

Table 8. -- continued

Distance from inlet (in.)	Capture velocity (ft/min)	Distance from inlet (in.)	Capture velocity (ft/min)
Fishmouth Attachment			
Total flow = 1.47 m^3 (52 f^3)/min		Total flow = 1.10 m^3 (39 ft^3)/min	
0	1600 (estimate)	0	1300 (estimate)
1	Can't read	1	Can't read
2	Can't read	2	Can't read
3	380	3	290
4	330	4	240
5	280	5	210
6	220	6	150
7	140	7	90
8	80	8	50

Distance from inlet (in.)	Capture velocity (ft/min)	%	Distance from inlet (in.)	Capture velocity (ft/min)	%
Overhead Attachment					
Total flow = 1.44 m^3 (51 ft^3)/min			Total flow = 0.57 m^3(20 ft^3)/min		
0	800	100	0	280	100
1	450	56	1	160	57
2	230	29	2	100	32
3	130	16	3	60	21
4	70	9	4	30	10
5	50	6	5	20	7
6	35	4	6	Can't read	

Distance from inlet (in.)	Capture velocity (ft/min)	%	Distance from inlet (in.)	Capture velocity (ft/min)	%
Drawer Attachment					
Total flow = 1/50 m^3 (53 ft^3)/min			Total flow = 0.57 m^3 (20 ft^3)/min		
0	800	100	0	310	100
1	430	54	1	220	71
2	240	30	2	130	42
3	140	18	3	70	23
4	70	9	4	30	10
5	35	4	5	20	7

TABLE 9. AIR SAMPLING DATA - HAZARDOUS METALS

Equipment: High-Speed Lathe
Vacuum Attachment: Ticonium lathe built-in attachment
Grinding Operation: Desprue, contour polish partial fr..mework

Substance	Air Concentrations (mg/m^3) Capture Vel=0	Capture Vel=60	Capture Vel=100	TLV
Chromium	4.41	0.05	0.05	.5
Nickel	1.37	0.1	0.1	1.0
Beryllium	0.0002	0.0002	0.0002	0.002
Molybdenum	0.5	0.5	0.5	10.0
Manganese	0.5	0.5	0.5	5.0
Sampling Time(min)	70	60	75	

TABLE 10. AIR SAMPLING DATA: SILICA

Equipment: Lab Handengine
Vacuum Attachment: None
Grinding Operation: Contour and smooth 2 porcelain crowns

Substance	Air Concentration (mg/m^3)
Silica	0 mg/m^3

Sampling time = 30 min

Note: Analysis of bulk sample indicated it contained 2.9% silica (quartz)

TABLE 11. AIR SAMPLING DATA: DUST

Equipment: Lab Handengine Grinding Operation: Key 2 sets of casts, trim 2 dies

Vacuum attachment	Sanding time (min)	Total flow (ft^3/min)	Distance to inlet (in.)	Cap vel (ft/min)	Air conc. (mg/m^3)	PEL (mg/m^3)
None	3	N/A	N/A	0	82.4	5.0
Fishmouth	4	60	8 1/4	100	*	5.0
Fishmouth	4	44	8 1/4	60	*	5.0
Fishmouth	12	30	8 1/4	45	*	5.0

Table 11. -- continued

Vacuum attachment	Sanding time (min)	Total flow (ft^3/min)	Distance to inlet (in.)	Cap vel (ft/min)	Air conc. (mg/m^3)	PEL (mg/m^3)
Drawer	3	20	2 5/8	100	*	5.0
Drawer	3	20	2 5/8	100	*	5.0
Drawer	12	15	2 5/8	85	4.2	5.0
Drawer	3	10	2 5/8	50	16.5	5.0
Overhead	3	50	4	65	*	5.0
Overhead	12	30	4	50	*	5.0
Overhead	12	20	4	35	*	5.0
Equipment: Slow-Speed Bench Lathe Grinding Operation: Key 2 sets of casts, trim 2 dies						
Fishmouth	12	44	8 1/4	60	2.7	5.0
Fishmouth	4	44	8 1/4	60	1.6	5.0

*Indicates concentration below detectable level.

END

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